

GAR PRECISION PRODUCTS DIVISION

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ELECTROFORMING

A. Definition

Electroforming is an electro-chemical process of metal fabrication: a technique of controlled deposition by means of an electrolyte. It provides a continuity of solid electro-deposited metal formed to complex shapes without the aid of forging, mechanical forming, welding, brazing, machining, grinding, etc.

1. At present the following metals are most widely used in electroforming: copper, iron, nickel and silver.

Organic addition agents have been and still are used to improve grain structure, increase brightness, reduce nodulation. However, most organic addition agents will be electroformed, along with the metal, into the cathode. If this cathode is subjected to sufficient heat, the organics decompose; the result may be porosity and embrittlement.

Electroforming has made its recent great advance through the development of the sulfamate nickel electrolyte.

The sulfamate nickel electrolyte is an aqueous electro-chemical system that deposits nickel with uniform mechanical properties. It permits stresses to be controlled from compressive, zero or tensile, without the use of organic addition agents.

The following data derived from electroformed sulfamate nickel specimens detail its performance:

Appearance of deposit	- Semi-matte
Color of Deposit	- White - 6
Electrical conductivity	- 7×10^{-6} ohm-cm
Thermal Conductivity	-.14 metric
Average tensile Strength	-90,000 PSI
Modulus of Elasticity (Tensile)	- $23 \text{ to } 24 \times 10^6$ PSI
Shear Modulus of Elasticity	- 11×10^6 PSI
Elongation in Two Inches	- 20 to 30 per cent

Hardness versus Temperature

Room Temperature	- 250 VHN Rockwell C 23
400 degrees C	- 225 VHN Rockwell C 18
800 degrees C	- 130 VHN Rockwell A 44
950 degrees C	- 100 VHN Rockwell B 54

Average Ultimate Tensile Strength

Room Temperature	- 130,000 PSI
700 Degrees Fahr.	- 38,000 PSI
750 Degrees Fahr.	- 34,500 PSI
800 Degrees Fahr.	- 30,000 PSI
950 Degrees Fahr.	- 23,400 PSI

Most sulfamate nickel electroforming baths operate at zero or slightly tensile internal stress: a requisite to reproduce diffraction gradients, parabolic mirrors, fresnel and lenticulated lenses accurately without distortion.

Stress is controlled by adjusting the agitation and temperature of the bath to the current density required.

These values are determined by means of spiral contractometer.

Mandrels can be made of plastic, epoxy, plaster, wax, wood, glass, low melting alloys, stainless steel, aluminum, and brass.

Permanent metal mandrels are used where there are no undercuts and can be extracted and used again.

Copper is used in electroforming applications mainly where high electrical and/or heat conductivity is required and in parts where the magnetic properties of sulfamate nickel cannot be tolerated.

2. Major Problems of Electroforming

A concentration of deposition of metal will occur on a cathode in those areas that are nearest the anodes, as well as on the outside edges, unless shielding, thieving, conforming anodes, or a combination of all three, are employed. The present state of the art requires a trial and error procedure to determine the placing and spacing of these members in order to approach uniform thickness deposition. This procedure requires production and destruction of several electroforms in order to arrive at the proper uniform thickness deposition.

Once these critical factors have been established, however, uniform production is assured.

The Vidigage has been employed to measure thickness and thus eliminating destruction of the model.

Electroforming into sharp corners of 90 degrees or less and into miniature recesses is not recommended.

GLOSSARY OF TERMS

Conforming anodes:	Anodes especially formed to the configurations of the cathode in order to provide uniform anode-cathode spacing, which will, in turn, provide uniform deposition on a cathode of intricate shape.
Electrolyte:	Solution in which the anode and cathode electrodes are immersed; contains metal, conductive vehicle, salts, etc., in accordance with particular type of electroforming required.
Electroplating:	In contrast to electroforming, electroplating is a treatment of surface for specific purposes such as: to harden surfaces, provide corrosive protection, increase or decrease absorption of certain frequencies of the spectrum improve or reduce conductivity of heat or electrical currents. In electroplating the following metals are used: chrome, copper, gold, lead, nickel, platinum and silver.
Mandrel:	A pattern or form which receives the deposition of metal and which serves to insure the desired configuration of the electroformed part.
Metallize:	To render the surface of a non-conductive material conductive, by means of precipitating a metal such as silver, copper, etc. out of solution through the use of a reducer, colloidal silver paint, finely divided graphite, bronze powder, vacuum sputtering, vapor deposition, and so forth.
Passivate:	To produce a molecular jellation on the surface of a metal. This jellation is conductive and will accept electroforming on its surface. After the electroforming has been completed, the two will separate.
Shields:	A non-conductive barrier to prevent or to reduce deposition of metal in specific areas.

Stress:

In the process of deposition of metals there are certain not too well understood conditions that occur. The metal may tend to shrink or have tensile stress; it may seem to expand causing compressive stress; or it may deposit without a tendency to do either, namely, zero stress.

**Space Vehicles
And Aircraft:**

- | | |
|--|------------------------------|
| a) Satellite Windows | f) Heat Exchangers |
| b) Wing tips | g) Facings for Epoxy Tooling |
| c) Leading edges | h) Hot Gas Ducting |
| d) Nose cones | i) Wind Tunnel Orifices |
| e) Missile & rocket hardware; nozzles etc. | j) Microwave Components |
| | k) Magnetic Shielding |

**Molds: (Opticals from
Plastics):**

- a) Fresnel Lenses
- b) Lenticulated Lenses
- c) Reflective Lenses
- d) Reflectors and Collectors
- e) Mirrors (Parabolic & Spherical)

**Molds: (Injection, Compression,
Slush & Casting):**

- a) Foils
- b) Masks and Stencils
- c) Type Cylinders
- d) Switch Plates
- e) Sinks or Wash Basins
- f) Fruit Bowls, Auto Ornaments.